Ministry of Education and Science of Ukraine

ODESSA NATIONAL ACADEMY OF FOOD TECHNOLOGIES

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2020

PROCEEDINGS

Black Sea Science International Competition of Student Scientific Works by Odessa National Academy of Food Technologies

ODESSA, ONAFT 2020

Ministry of Education and Science of Ukraine

Odessa National Academy of Food Technologies

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2020

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Proceedings of International Competition of Student Scientific Works «Black Sea Science 2020» contain the works of winners of the competition.

The author of the work is responsible for the accuracy of the information.

Odessa National Academy of Food Technologies, 2020.

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3. INFORMATION TECHNOLOGIES, AUTOMATION AND ROBOTICS

INFORMATION MODEL OF THE APPLICATION OF A HELLIOSYSTEM FOR THE NEEDS OF STUDENT DORMITORY IN THE BLACK SEA REGION

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***Abstract**. The paper investigates the possibility of using solar energy in the hot water system, using the example of the Odessa Technical College of the Odessa National Academy of Food Technologies dormitory, for improve living conditions. The needs student dormitory in hot water at a confidence interval of 95 ± 5% is confirmed by the results of a poll in a representative sample of students living in a dormitory.*

The paper identified requirements (quantitative characteristics) of thermal energy for the needs of a typical student dormitory (corridor type) in the Black Sea region, the optimal angle of inclination of the solar collectors installation is determined, the type and the required amount of solar system equipment are calculated. According to the results of the study, the optimal variants of the number of vacuum solar collectors at the implementation site are determined, which differ significantly by seasons.

Generalization, mathematical and computer modeling techniques were used in writing of the information model study. Computer simulation is done by tabulating functions in MS Excel and plotting 3D graphs in Matlab.

As a result of the research, it was found that the use of solar energy in the student dormitory can provide it with hot water in the spring and autumn period of the year.

***Key words**: Information Model, Computer Modeling, Solar System, Vacuum Solar Collectors, student dormitory (corridor type) of the Black Sea region.*

I. INTRODUCTION

Theme actuality:

The functioning and procedure of settlement of persons in dormitories during studies in Ukraine is governed by the Housing Code of Ukraine (Housing Code, Article 127), the Student Dormitory Regulations developed by the educational institution in accordance with the Model Regulations and the Dormitory Rules and Conditions [1]. As a rule, the supply of hot water for domestic needs of students living in a student dormitory in the Black Sea region is interrupted between April and September and is renewed from October of the current year. This is due to the existing integrated gas heating system and hot water supply.

According to the results of a sociological survey among students residing in the dormitory of the Odessa Technical College of the Odessa National Academy of Food Technologies (OTC ONAFT), the need to improve the living conditions, namely the need to supply hot water throughout the year was determined (see Fig.1). Alternative renewable energy sources (RES) are proposed to meet domestic hot water requirements.

One of the most promising types of RES is solar energy. Due to this, it is possible to fully satisfy the demand for hot water in the spring-autumn period of time.

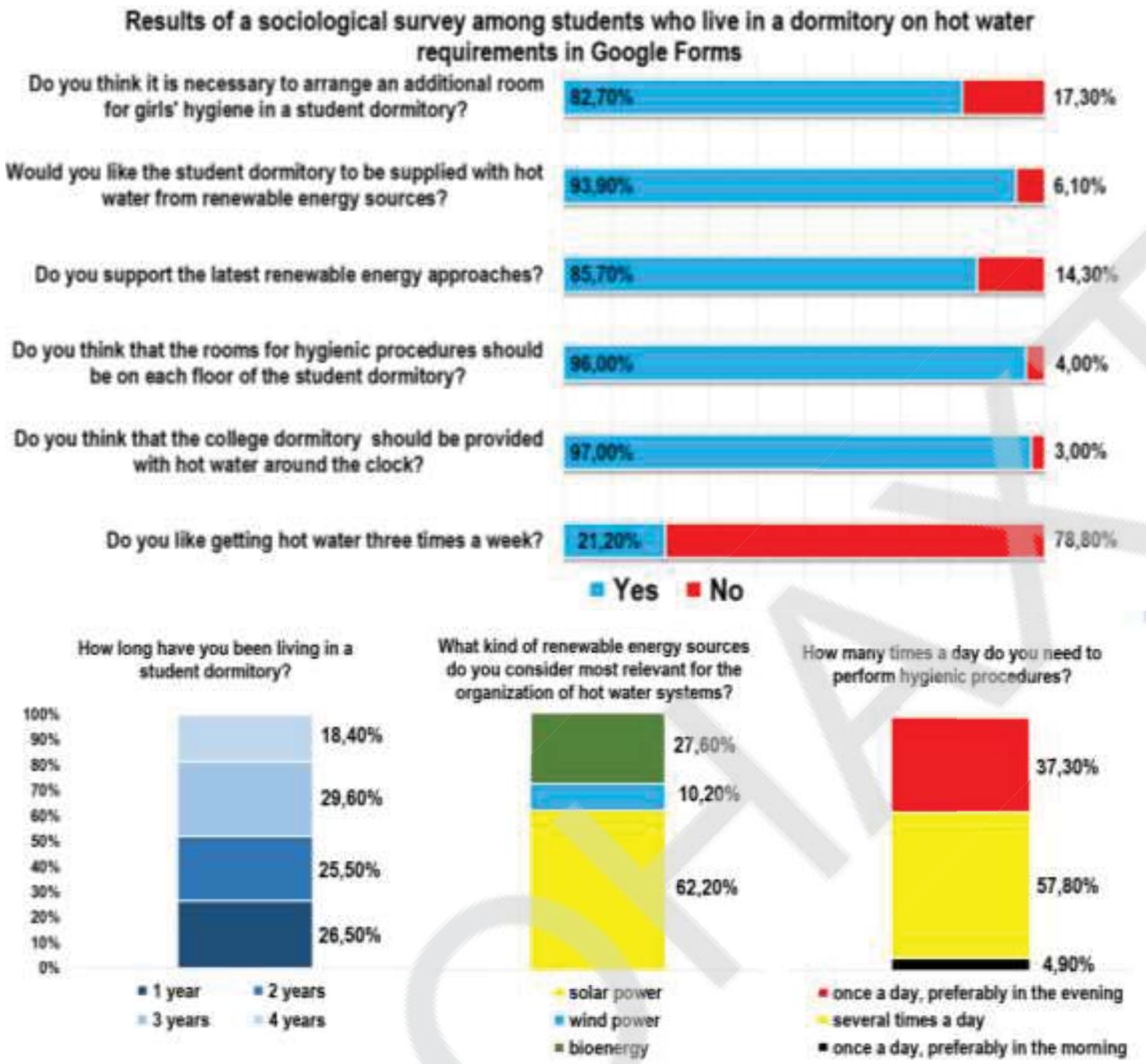


Figure 1 – Results of a sociological survey among students who live in a dormitory on hot water requirements in Google Forms

The most efficient use of solar energy is possible when using solar collectors. It is the absorbing panel of the solar collector that under the influence of solar radiation (infrared component) transforms solar energy into thermal, for the subsequent heating of domestic water. Modern solar systems allow you to save up to 60% of the energy required to heat water per year.

Research methods:

Generalization, mathematical and computer modeling techniques were used in writing of the information model study. Computer simulation is done by tabulating functions in MS Excel and plotting 3D graphs in Matlab.

Scientific novelty of the work:

- identified requirements for thermal energy for the needs of a typical student dormitory (corridor type) in the Black Sea region;
- determined the optimal tilt angle of the installation of solar collectors and the estimated amount of necessary equipment for the solar system.

Practical value:

As a result of a conducted research it was found that the use of solar energy in a student dormitory will allow to provide hot water in the spring and autumn periods of the year.

Structure of the research paper:

The research paper consists of an introduction, two sections and a conclusion.

The first section provides an overview of current solar energy technologies. Presented variants for using solar energy for hot water supply.

The second section describes the development of an information model of a hot water supply system utilizing a solar energy for a typical floor of a student dormitory in the Black Sea region.

The conclusion provides suggestions for the practical implementation of the selected solar system equipment.

II. Analytical review of the literature

Increasing the use of energy from renewable sources and alternative fuels is considered an important part of Ukraine's strategy to conserve traditional fuel and energy resources and reduce the associated environmental impact. The adopted Law of Ukraine "On Alternative Energy Sources" defines legal, social, economic, environmental and organizational principles of the use of alternative energy sources, as well as encouraging increase of their use [2].

The problems of the use of alternative energy are covered in the works of leading domestic scientists, namely: S.O. Kydria, I.V. Bondarenko, H.B. Varlamova, I.A. Volchyna, O.V. Zur'yan, A.K. Shyndlovskyi, V.F. Shinkarenko etc. [4-7]

Renewable energy sources in Ukraine are well studied and described, but it is difficult to determine their economic potential. In 2001, at the request of the State Committee for Energy Conservation, a group of Ukrainian scientists created the Ground Atlas of the Energy Potential of Renewable Energy in Ukraine [8]. The Atlas provides information on the territorial distribution of various renewable energy sources and the calculation of their physical, technical and economic potential. The Atlas certifies that Ukraine has a large enough potential of all types of RES, outlines the overall picture of existing RES implementation and recommendations for further development. For example, it is recommended to use flat solar collectors in the southern regions of Ukraine.

Modern technologies for the production of alternative energy sources include:

- use of solar energy for heat supply systems by means of collectors and passive solar heating systems;
- use of geothermal water for heat supply;
- use of heat pumps of small and medium capacity for heat supply of individual houses and utilization of thermal emissions, and high power - in heat pumping stations for replacement of small and medium-sized boilers;
- use of agricultural waste to produce biogas as fuel;
- other energy sources.

Let's take a closer look at the benefits of using helliosystems for domestic use. The task of solar energy is to heat water for domestic use during the warm season, where it is economically justified.

A helliosystem (solar collector or solar system) is a device for effectively converting solar energy into thermal energy and heating water. A solar thermal system typically consists of a solar thermal collector, a water storage system (a tank) for a control system and a pump system.

There are a large number of solar systems in the world that are structurally different from one another. The classification of the solar heat supply system is shown on Fig. 2.

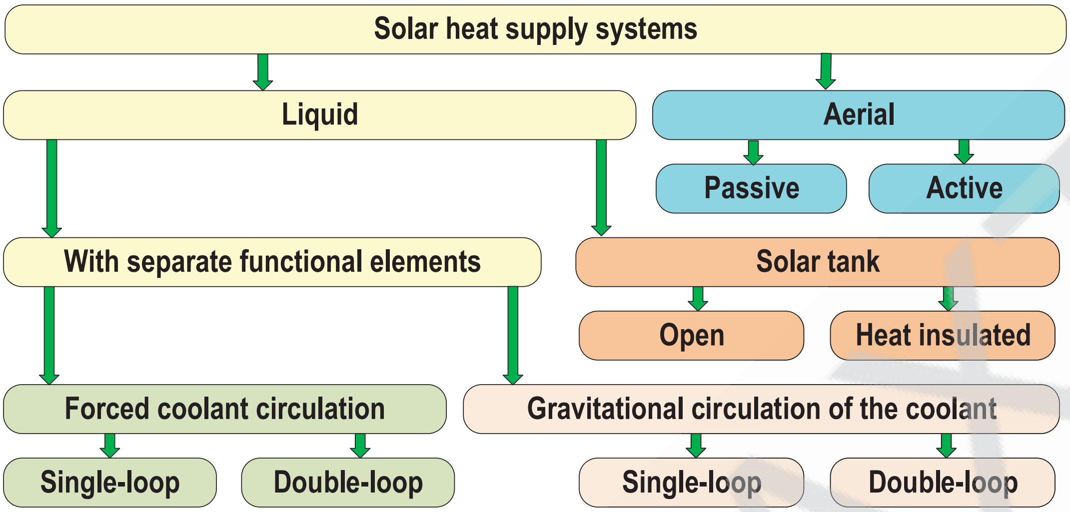


Figure 2 – Classification of solar heat supply systems

The most efficient use of solar energy is possible when using solar collectors. It is the absorbing panel of the solar collector that under the influence of solar radiation (infrared component) transforms solar energy into thermal, for the subsequent heating of domestic water. Modern solar systems allow you to save up to 60% of the energy required to heat water per year.

The amount of solar energy that reaches the surface of 20,000 km^2 can be used to supply the population of the globe.

The use of solar energy in many countries is beginning to take an important place. Water heating in household appliances is widespread in Australia, Greece and the Mediterranean East. Several million dollars worth of solar energy produced annually in the USA and Japan. In Ukraine the highest energy of solar radiation is in the Black Sea region (Fig. 3).

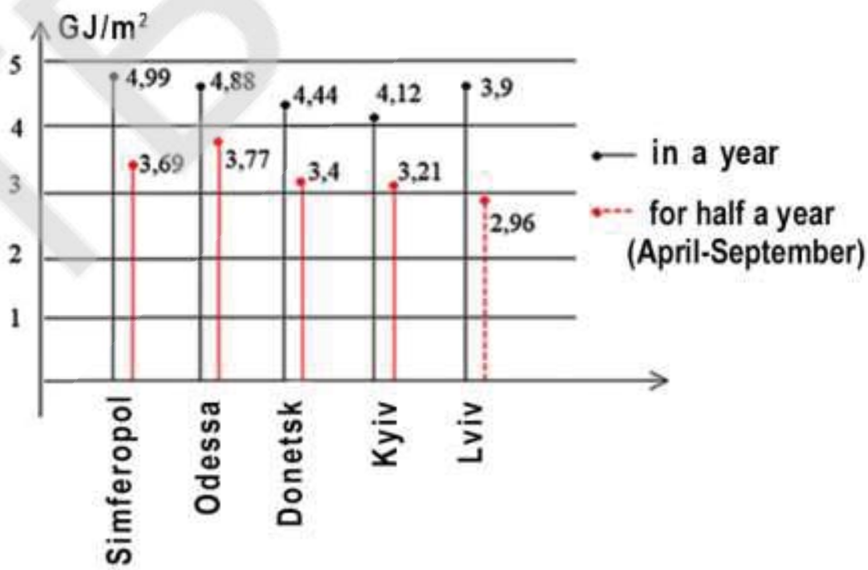


Figure 3 – Solar radiation energy reaching the surface of the land in Ukrainian cities

Solar installations (solar power plants) convert solar radiation into thermal (for heating water to 50-60°C in baths, laundries etc.) or electrical (photoelectric, thermoelectric and thermodynamic) energy. A solar installation with a machine cycle is called a solar power station.

The collector most effectively manifests itself in the southern region of Ukraine in the summer with good sunny weather, but can successfully work even on sunny winter days. For example, the efficiency of vacuum collectors averages 65-70%. It should be also considered that the vacuum collector absorbs not only direct but also scattered sun rays, and works successfully even at negative ambient air temperatures [9].

III. Object, subject and methods of research

Characteristics of the object of study

The purpose of the study is to investigate the possibility of using solar energy in the hot water system, using the example of the Black Sea OTC ONAFT dormitory. Figure 4 shows the layout of the premises with the requirement for hot water in the student dormitory.

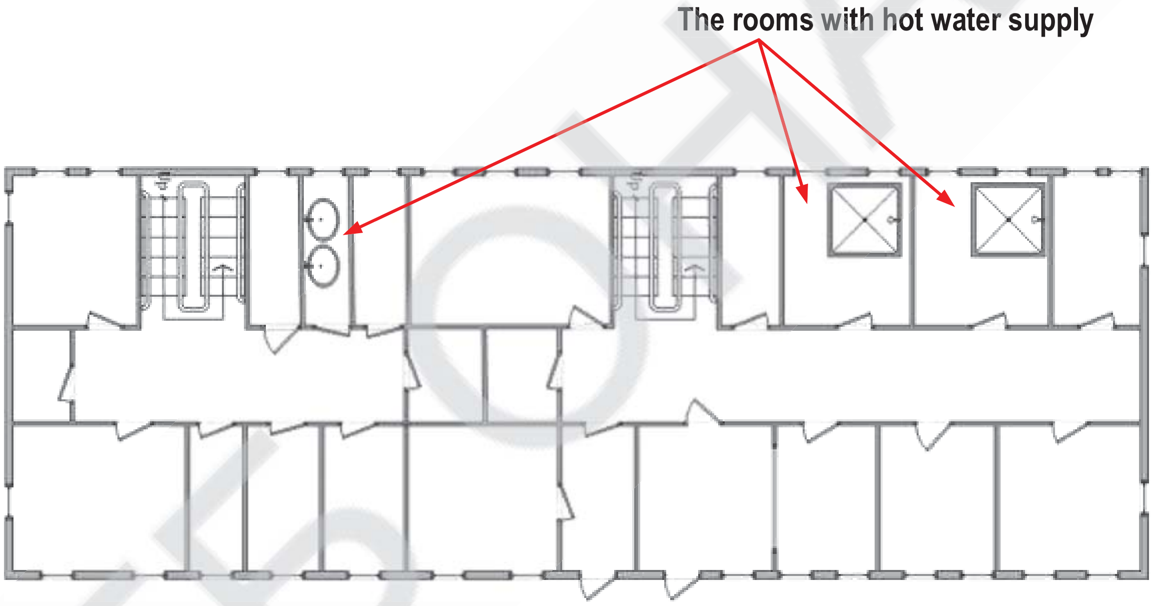


Figure 4 – Floor plan of a student dormitory with rooms with hot water supply

Most solar collectors have the elements shown on fig. 5.

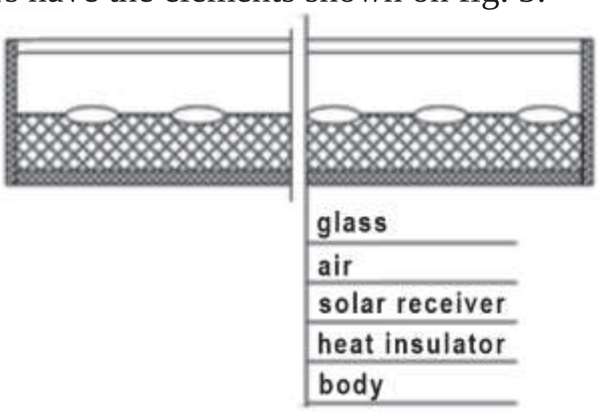


Figure 5 – Elements of solar collectors

The most efficient solar collectors are made with an aluminum housing, two layers of glass and a solar collector, which has a coating that provides minimal heat losses to the collector during radiation heat exchange. Such collectors are expensive enough, and this is not always justified by their additional thermal conductivity. Therefore, cheaper collectors with steel housings and solar collectors that are protected by a single layer of glass are often used. The scheme of the simplest solar installation is shown on Fig. 6.

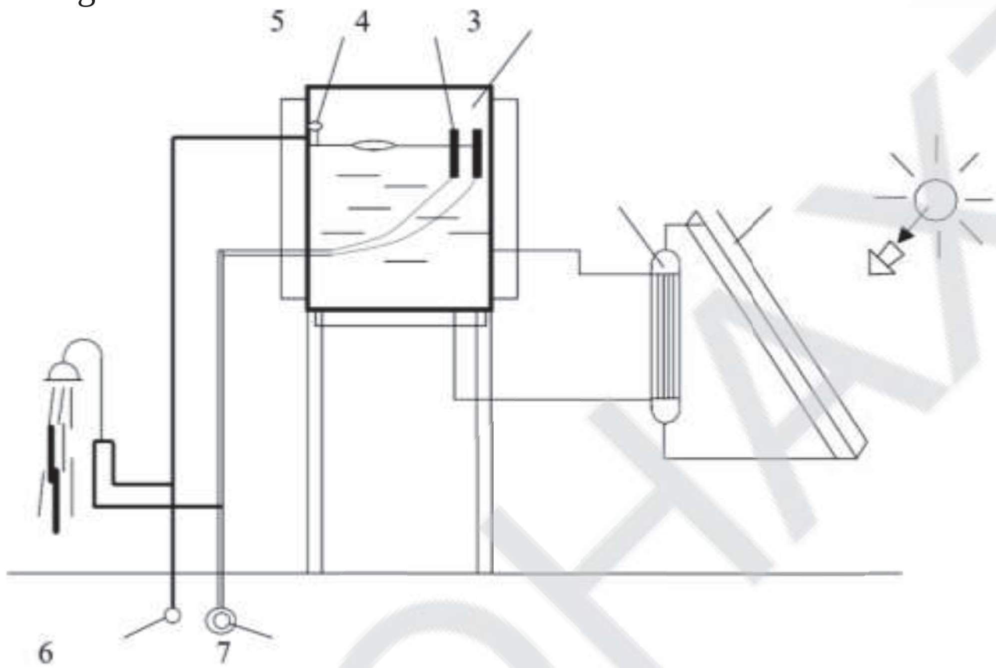


Figure 6 – **Scheme of solar installation for hot water supply**
1 – solar boiler; 2 – heat exchangers; 3 – storage tank;
4 – float; 5 – float valve ; 6 – water supply system;
7 – hot water supply line.

The scheme consists of two circuits of circulation. The first circuit is a solar boiler 1, which has pipelines connected by solar collectors, where water circulates during natural excitation. Water that is heated in solar collectors under the influence of gravitational pressure is directed to a heat exchanger 2, where the heat is transferred to the tap water that is filled in thermally insulated storage tank 3. As a result of stratification, the water temperature in the tank will be the same. The highest water temperature will be reached in the upper zone of the tank. In order for the hot water supply network to receive the highest temperature water, the shut-off pipe is attached to the float 4. The tank is filled through a float valve 5, which is connected to the water supply system 6, and the heated in solar installation water is directed to the consumers via the hot water supply line 7.

Solar systems for hot water supply are widespread in recreational facilities, in residential areas where facilities can be used to reduce the cost of purchasing fuel or paying for the heat in summer.

A patent review of works in the field of solar energy has shown that currently the largest number of new patents among various types of "green" energy technologies are issued in the field of solar generation. This was reported by WIPO (World Intellectual Property Organization) experts at a seminar held at the Europe-Asia Forum (ASEM).

Computer model of the solar system for domestic heat supply

Let's look at the results of modeling the solar system in Matlab and the MS Excel spreadsheet based on a symbolic linear programming model for the student dormitory system of the Odessa Technical College of the Odessa National Academy of Food Technologies (OTC ONAFT).

Solar water heating system for household needs is planned in Odessa Technical College, which is located at latitude 46.47 NN. The system has to meet the needs of N = 38 consumers, each one daily use V = 30 liters of hot water at a temperature of $T_{h.w.}$ = 55°C. Temperature of cold water in the water supply system of Odessa city $T_{c.w.}$ = 10°C. Collectors set at an angle of 45° to the horizon and oriented south. Volume of water in the storage tank $V_{s.t.}$ = 300 liters.

To calculate the heat capacity of the solar collector we need to determine the monthly average daily amount of solar energy, MJ/(m^2·day) which enters the collector surface. It's determined by the formula:

$$E_k = E \cdot R \qquad (1)$$

where E is the average monthly total solar radiation on a horizontal surface, R is the ratio of average daily quantities solar radiation coming to the surface at an inclined and horizontal surface.

$$R = \left(1 - \frac{E_D}{E}\right) \cdot R_d + \frac{1+\cos\beta}{2} \cdot \frac{E_Д}{E} + \rho \cdot \frac{1-\cos\beta}{2} \qquad (2)$$

where E_D *is* the average monthly amount of solar energy that is dissipated

(diffused) arriving on a horizontal surface, MJ/(m^2·day), R_d – direct radiation conversion factor from horizontal to the surface inclined, β – the angle of the collector to the horizon, deg.; ρ – the reflection coefficient for the surface of the land: in summer it's 0.2, and in winter at snow – 0.7.

The monthly average value of the coefficient is determined by the formula:

$$R_d = \frac{\cos(\varphi-\beta)\cdot\cos\delta\cdot\sin\omega_3' + \frac{\pi}{180}\cdot\omega_3'\cdot\sin(\varphi-\beta)\cdot\sin\delta}{\cos\varphi\cdot\cos\delta\cdot\sin\omega_3 + \sin\varphi\cdot\sin\delta\cdot\frac{\pi}{180}\cdot\omega_3} \qquad (3)$$

where φ – is the latitude, deg.; δ – declination of the Sun, deg.; ω_3 and ω_3' – sunset angle on horizontal and inclined surfaces, deg.

The angle of inclination of the Sun in every day n is equal to:

$$\delta = 23{,}45 \cdot \sin\left(360 \cdot \frac{284+n}{365}\right) \qquad (4)$$

The load of hot water supply is determined by the formula:

$$L_{\text{нw}} = M \cdot N \cdot 1000 \cdot (T_{avg} - T_{cold}) \cdot \rho \cdot \mathrm{C_p} \qquad (5)$$

where M is the number of days in a month, N is number of people – 38, T_{avg} – average temperature of hot water – 55°C, T_{cold} – temperature of cold water – 10°C, ρ is the density of water – 1 kg/l, $\mathrm{C_p}$ is the heat capacity – 4190 J/kg·K.

The amount of heat coming from the heat sink to 1 solar collector is determined by the formula:

$$Q_{us} = F_R' \cdot \lfloor E_k \cdot (\tau\alpha) - U_L \cdot (T_T - T_a) \rfloor \qquad (6)$$

де Q_{us} – where is the useful thermal power of the solar collector, W/m^2, E_k – is the density flow of total solar radiation in the area of reservoir, kW/(m^2·day), τ – bandwidth of transparent insulation, α is the panel absorbency of the collector, U_L is the total coefficient of thermal losses, W/(m^2·K); T_T is the average temperature of the coolant in the collector, K; T_a is the ambient air temperature, K, F'_R – is the coefficient of efficiency of the absorbing panel, that takes into account that the average panel temperature is always above the average liquid temperature.

There are several varieties of complexes with alternative energy sources used for hot water supply. After analysis of the object of study and its hot water operating system we decided that using the vacuum solar collector ATMOSFERA SVC-NANO with 30 tubes that is certified in Ukraine is more rational and efficient [10]. That model uses high-performance "3-hi solar" vacuum tubes with system "heatpipe" (capacitor diameter 14mm).

The SVC-Nano collector is effective for year-round use. Collector efficiency - up to 92%. It has steady performance in cloudy weather.

The aluminum frame of collector reduces the load on the carrier roof of a construction. The frame construction is designed to install a manifold on a sloping surface. Thermal insulation of heat exchanger is 45 mm.

Calculations were made for the hardware and software complex parameters of vacuum solar collectors, namely the load of hot water supply for each month, the thermal capacity of the solar collector, the volume of the battery tank and its selection.

The calculation is made for ATMOSFERA SVC-NANO (30 tubes), with the following characteristics:

– absorption coefficient of panel F'_R= 0,77;
– total coefficient of heat loss U_L= 0,8 W/(m^2·K);
– $(\tau\alpha)$ = 1,08;
– average coolant temperature in the collector T_T= 328 K.

The desired area of collectors A (m^2) is selected on a clear day of the warmest month of the year (August):

$$\text{A} = \frac{V_{\ h.w.}}{Q_{day}} \tag{7}$$

where $V_{h.w.}$ is daily consumption of hot water, l.; Q_{day} is the daily productivity of 1m^2 solar collector, which is determined by the formula, l/m^2·day:

$$Q_{day} = \frac{Q_{us}}{m \cdot c \cdot (T_{avg} - T_{cold})} \tag{8}$$

where Q_{us} is the amount of useful heat produced by the collector, kW·h; *m* is the specific gravity of water, kg/l ; *c* – heat capacity of water, kWh/ m^2·°C; *c* = 0,001 kW·h/m^2·°C; T_{avg} is the average temperature of hot water – 55°C, T_{cold} is the temperature of cold water – 10°C.

$$Q_{day} = \frac{4752}{1 \cdot 0{,}001 \cdot (55-10)} = 105{,}6 \text{ (l/m}^2\text{·day)}$$

Required area of solar collectors:

$$\text{A} = \frac{1710}{11{,}63} = 16{,}2 \text{ m}^2$$

Number of vacuum collectors:

$$K_{v.c} = \frac{A}{S_{absorb.}} \tag{9}$$

where $S_{absorb.}$ – where is the absorber area defined in the technical specifications of the solar collector – 2,41 m^2.

The optimum variant of the parameters of the hot (domestic) water supply system was calculated in accordance with the model of thermal balance of the solar heat supply system based on computer simulation of technical systems using the MS Excel spreadsheet and Matlab.

Computer simulation is done by tabulating functions in MS Excel and building 3D graphs in Matlab in three stages: the first step is to create a tabular model of linear programming; the second stage investigates the model performance, which depends on the angle of inclination of the solar collectors installation in the Odessa region; in the third stage, a symbolic model of linear programming creates its representation in the MS Excel spreadsheet.

VI. Results of paper

Based on the obtained solar system data, a framework model was created in the Matlab system in 3D on the base of two-dimensional function using a coordinate grid, where in the space (x, y, z) on the axes *ox/oz* the counts correspond to the sequence of months in the current year and on the axis *oy* the time angle of sunset / sunrise on an inclined surface is displayed, affecting the average monthly values of the direct radiation conversion factor from horizontal to inclined surface.

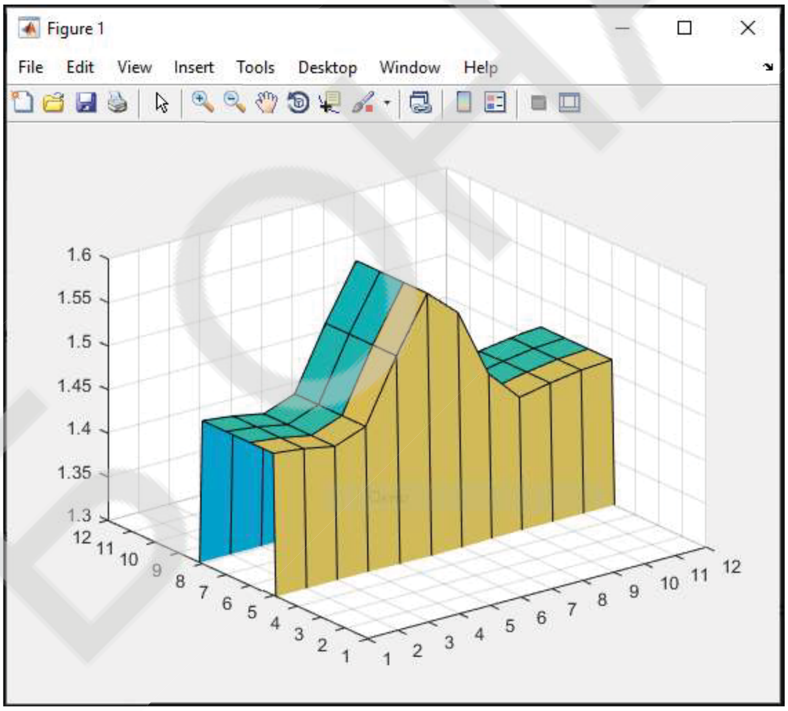
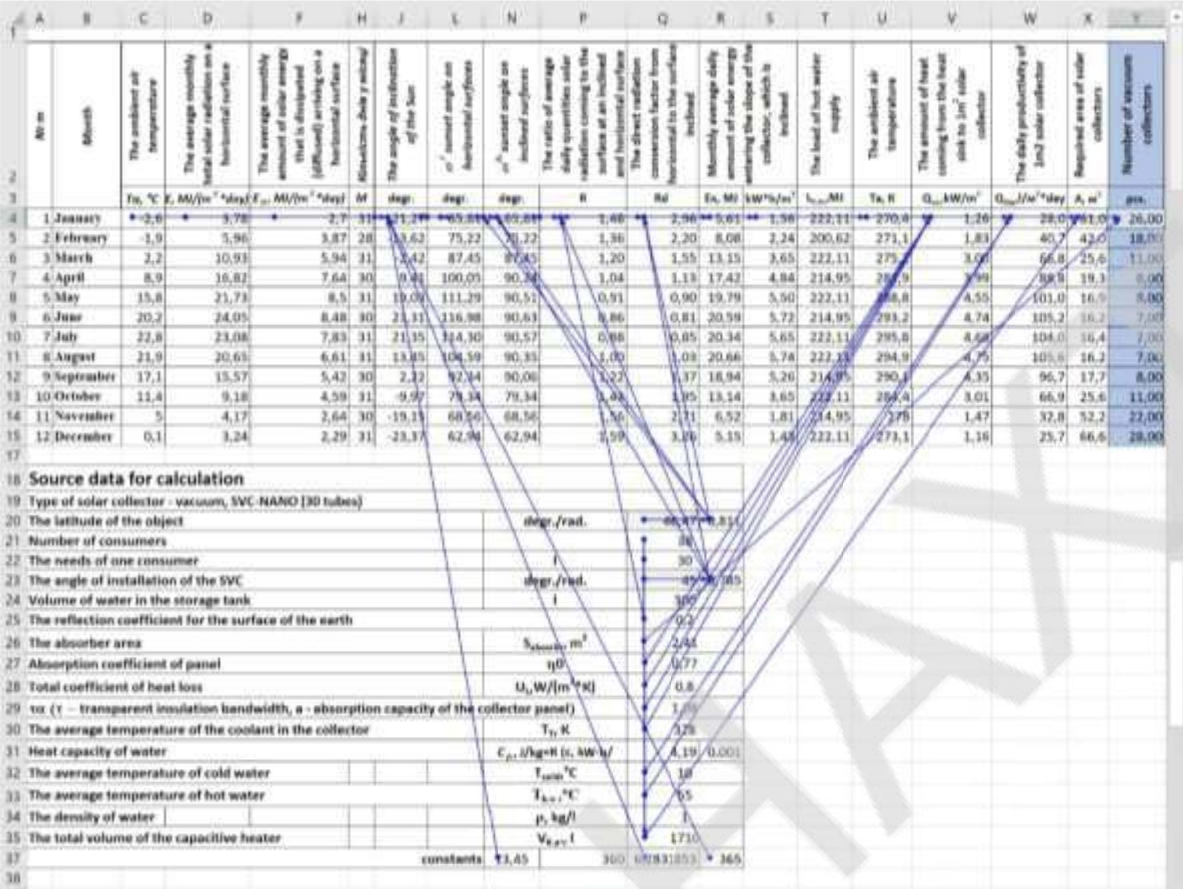


Figure 7 - Model of the ratio of the average monthly amounts of solar radiation arriving at the inclined surface and the horizontal surface by months of the year

Using the developed model it is possible to calculate the characteristics of the ATMOSFERA SVC-NANO 30 solar system for different angles of inclination, namely 35, 45, 55 degrees, by months of the year.

Figure 8 presents the results of the model parameters calculation in MS Excel.



№	Month	Tα, °C	E, MJ/(m²*day)	E_p, MJ/(m²*day)	M	degr.	degr.	degr.	R	Rd	Ea, MJ	kW*h/m²	L, MJ	Ta, K	Q, kW/m²	Q, l/m²*day	A, m²	pcs.
1	January	-2,6	3,78	2,7	31	21,2[illegible]	65,8[illegible]	65,8[illegible]	1,48	2,96	5,61	1,58	222,11	270,4	1,26	28,0	[illegible]	26,00
2	February	-1,9	5,96	3,87	28	-13,62	75,22	75,22	1,36	2,20	8,08	2,24	200,62	271,1	1,83	40,7	42,0	18,00
3	March	2,2	10,93	5,94	31	-2,42	87,45	87,45	1,20	1,55	13,15	3,65	222,11	275	3,0[illegible]	66,8	25,6	11,00
4	April	8,9	16,82	7,64	30	9,41	100,05	90,3[illegible]	1,04	1,13	17,42	4,84	214,95	[illegible]	3,99	[illegible]	19,3	9,00
5	May	15,8	21,73	8,5	31	19,0[illegible]	111,29	90,51	0,91	0,90	19,79	5,50	222,11	[illegible]	4,55	101,0	16,9	9,00
6	June	20,2	24,05	8,48	30	23,11	116,98	90,63	0,86	0,81	20,59	5,72	214,95	293,2	4,74	105,2	16,2	7,00
7	July	22,8	23,08	7,83	31	21,15	114,30	90,57	0,88	0,85	20,34	5,65	222,11	295,8	4,6[illegible]	104,0	16,4	7,00
8	August	21,9	20,65	6,61	31	13,85	104,59	90,35	1,00	1,08	20,66	5,74	222,11	294,9	4,75	105,6	16,2	7,00
9	September	17,1	15,57	5,42	30	2,22	92,34	90,06	1,22	1,37	18,94	5,26	214,95	290,1	4,35	96,7	17,7	8,00
10	October	11,4	9,18	4,59	31	-9,97	79,34	79,34	1,4[illegible]	1,95	13,14	3,65	222,11	284,4	3,01	66,9	25,6	11,00
11	November	5	4,17	2,64	30	-19,15	68,56	68,56	1,56	2,71	6,52	1,81	214,95	278	1,47	32,8	52,2	22,00
12	December	0,1	3,24	2,29	31	-23,37	62,94	62,94	1,59	3,26	5,15	1,43	222,11	273,1	1,16	25,7	66,6	28,00

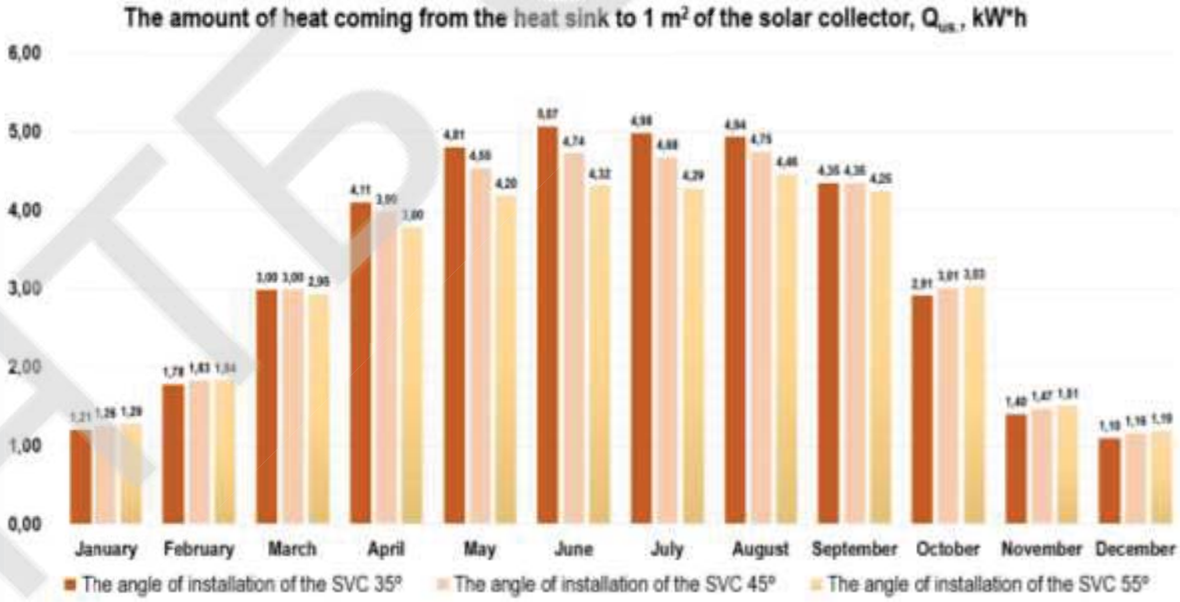
Source data for calculation

Type of solar collector - vacuum, SVC-NANO (30 tubes)

The latitude of the object	degr./rad.	[illegible]	[illegible]
Number of consumers		[illegible]	
The needs of one consumer	l	30	
The angle of installation of the SVC	degr./rad.	45	[illegible]
Volume of water in the storage tank	l	300	
The reflection coefficient for the surface of the earth		0,2	
The absorber area	$S_{absorber}$, m²	2,44	
Absorption coefficient of panel	η0	0,77	
Total coefficient of heat loss	U_L, W/(m²*K)	0,8	
τα (τ – transparent insulation bandwidth, α - absorption capacity of the collector panel)		1,0[illegible]	
The average temperature of the coolant in the collector	T_T, K	328	
Heat capacity of water	C_p, J/kg*K (c, kW*h/	4,19	0,001
The average temperature of cold water	T_{cold},°C	10	
The average temperature of hot water	T_{hot},°C	55	
The density of water	ρ, kg/l	1	
The total volume of the capacitive heater	V_{hot}, l	1710	
constants	13,45	360	[illegible] 365

Figure 8 – Results of the model parameters calculation

Below are the results of calculating the parameters of the model of the solar system, depending on the angle of inclination by months of the year in infographics (see Fig. 9) and tabular form (see table 1).



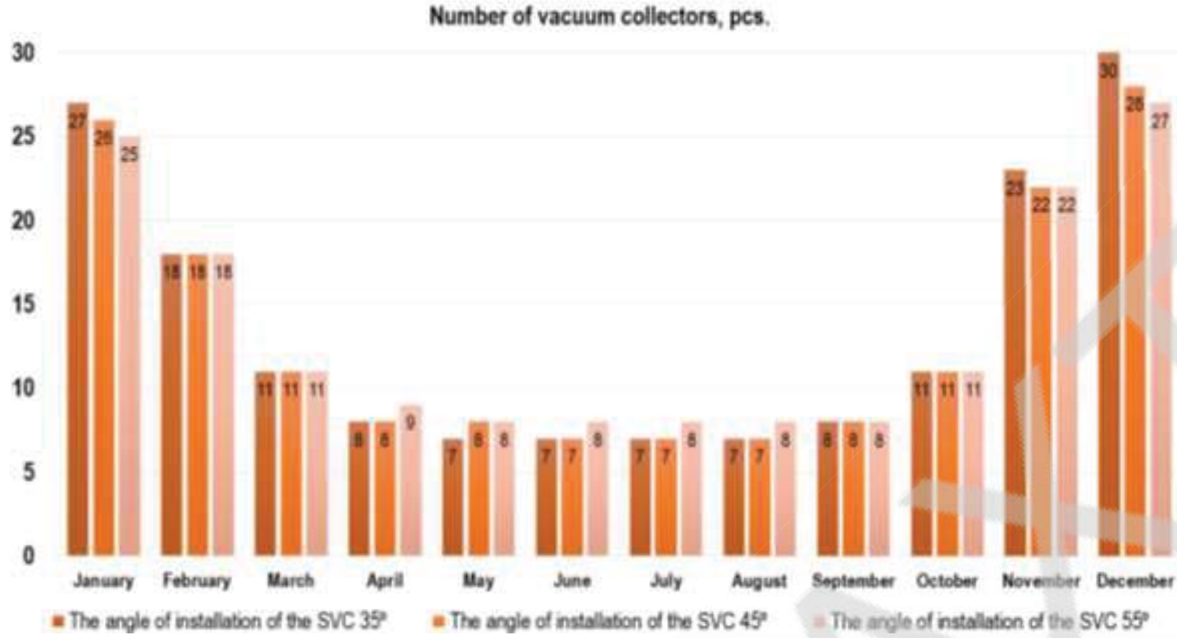


Figure 9 – The main indicators of the use of the solar system of ATMOSFERA SVC NANO 30 by months of the year in a student dormitory of the Black Sea region.

Table 1

Specifications for the relationship of the number of solar collectors from the angle of inclination

нm №	Month	Number of vacuum collectors, pcs.			The amount of heat coming from the heat sink to 1 m^2 of the solar collector, Quse, kW*h		
		The angle of installation of the SVC 35°	The angle of installation of the SVC 45°	The angle of installation of the SVC 55°	The angle of installation of the SVC 35°	The angle of installation of the SVC 45°	The angle of installation of the SVC 55°
11	**January**	27	26	25	1,21	1,26	1,29
22	**February**	18	18	18	1,78	1,83	1,84
33	**March**	11	11	11	3	3	2,95
44	**April**	8	8	9	4,11	3,99	3,8
55	**May**	7	8	8	4,81	4,55	4,2
66	**June**	7	7	8	5,07	4,74	4,32
77	**July**	7	7	8	4,98	4,68	4,29
88	**August**	7	7	8	4,94	4,75	4,46
99	**September**	8	8	8	4,35	4,35	4,25
110	**October**	11	11	11	2,91	3,01	3,03
111	**November**	23	22	22	1,4	1,47	1,51
112	**December**	30	28	27	1,1	1,16	1,19

V. CONCLUSIONS

The relevance of the study of the information model of the solar system for the needs of the Black Sea student dormitory in hot water at a confidence interval of 95 ± 5% is confirmed by the results of a poll in a representative sample among students living in the OTC ONAFT dormitory.

Thus, according to the results of the study, the optimal variants of the number of vacuum solar collectors at the implementation object, which differ significantly by seasons, are calculated in the MS Excel spreadsheet and Matlab. The option "the more the better" in this case is not suitable, because in summer you need to dump unused hot water into the sewerage. Given the uneven use of hot water in the dormitory by month, we recommend 8 solar systems ATMOSFERA SVC-NANO 30 with a capacity of 300 liters per day.

VI. LITERATURE

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